Attorney Docket No. TAV-1829

TITLE

Method and Apparatus for Reducing Segregation in Metallic Ingots

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BACKGROUND OF THE TECHNOLOGY

FIELD OF TECHNOLOGY

[0001] The present disclosure relates to methods and apparatus for producing metallic ingots, as well as to articles of manufacture made from materials processed according to the methods and/or using the apparatus.

DESCRIPTION OF THE BACKGROUND OF THE TECHNOLOGY

[0002] Specialty alloys are often used in applications where high performance characteristics are of paramount importance. Such applications include: high strength components for jet engines made from forgings, castings, and bar stock; cryogenic and liquid fuel rocket components, such as engines, nozzles, and combustion components; FGD systems; nuclear and chemical processing industry (CPI) pumps; land based turbine wheels, spacers, turbine compressor blades and discs; parts for steam and gas turbines; cutting tools; airframe structural parts; valve parts; and chemical process equipment. Because of the demanding nature of these and other high performance applications, the

alloys typically must possess exceptional mechanical properties and have high corrosion resistance. To best achieve such characteristics, alloys must be substantially homogeneous. Producing alloys with a suitably high level of homogeneity requires the use of multiple refining processes, including, for example, a primary melt step such as vacuum induction melting (VIM), and secondary refining steps, such as, for example, electroslag remelting (ESR) and/or vacuum-arc remelting (VAR). Consumable electrodes of essentially the same alloy composition as the desired finished product are subjected to these various secondary treatment methods.

[0003] While VAR and ESR have many similarities, basic differences do exist. For example ESR is a refining technique normally conducted at atmospheric pressure with the energy for melting being provided by resistance heating of the slag. This is in contrast with VAR, which is conducted in a vacuum and at slower melt rates than ESR, with the energy for melting being provided by a DC arc. In one typical configuration, the conventional ESR process employs an open-bottom, water-cooled copper mold (also known as a withdrawal mold) containing an electrically conductive slag; a consumable electrode having the desired alloy chemistry in contact with the slag; an electrode feed mechanism adapted to advance the electrode toward the mold; and a high current, low voltage AC or, more rarely, DC power source.

[0004] The ESR process begins with the withdrawal mold resting on an electrically conductive base plate. An arc is struck between the base plate and the electrode, passing current through the consumable electrode to the slag and,

consequently, melting the slag. The heated slag melts the tip of the electrode contacting the slag. As the consumable electrode melts, droplets of the electrode material pass through the molten slag layer, and the alloy is refined. The alloy droplets then gather in the withdrawal mold and form a molten metal pool. As the molten pool cools and solidifies into an ingot, it passes through a transitional state between a liquid and a solid. The region of the ingot in this solid-liquid transitional state is conventionally referred to as the "mushy zone". As the ingot cools, both the mushy zone and the molten pool advance upward. As the ingot grows, either the mold moves upward away from the base plate, or the base plate is lowered away from the mold. In conventional ESR, the melt rate is adjusted so that the molten pool depth generally is maintained at the desired depth. In order to form ingots of large sizes, multiple electrodes can be melted using ESR.

[0005] ESR has been successfully used as a final melt step in forming small diameter ingots (defined herein as 16 inches (about 0.40 m) or less in diameter) and as an intermediate melt step for forming large diameter ingots (defined herein as greater than 16 inches (about 0.40 m) in diameter) of a variety of segregation-prone nickel-base and cobalt-base alloys with few oxide inclusions. This is because when ESR is used as the final refining step with alloys having a proclivity for segregation, small diameter ingots typically do not exhibit severe macro-segregation. However, larger diameter ingots produced by ESR from such alloys have exhibited significant macro-segregation defects. As used herein, and as is understood in the art, macro-segregation is a casting

defect in which alloying elements concentrate within regions of the ingot on a macro scale, which means that one of ordinary skill in the art may detect such defects by inspecting a suitably prepared surface using the naked eye. Macro-segregation can occur during production when, for example, certain alloying elements form secondary phases and concentrate. It follows that when macro-segregation occurs, elements comprising the alloy are not evenly dispersed throughout the alloy, and the alloy contains inhomogeneities on the macro scale. Thus, while products made from alloy regions having a desired chemistry may exhibit sufficient mechanical properties for the intended application, products including alloy regions containing macro-segregation defects may not have acceptable mechanical properties. For example, alloy regions affected by macro-segregation may be more likely to have lower ductility and elongation properties and lower Low Cycle Fatigue (LCF) life, which could result in premature part failure.

[0006] Alloy macro-segregation in large diameter ingots has been addressed by use of VAR as the final melt process. However, alloys produced in this way may include oxide clusters, which can produce flaws in products made from the alloys. Such flaws can also result in low ductility and premature part failure.

[0007] Conventional ESR also has been used as the final melt process to produce large diameter ingots, but the results generally have been unsatisfactory. While use of ESR can avoid the oxide cluster problems experienced with VAR, large diameter ingots made of segregation-prone alloys

processed using conventional ESR as the final melt process often exhibit severe macro-segregation.

[0008] A process useful for producing ingots having diameters greater than 16 inches (about 0.40 m) that are substantially free from oxide clusters and lack macro-segregation defects would be highly advantageous.

SUMMARY

[0009] One aspect of the present disclosure is directed to a novel electroslag remelting method for producing a metallic ingot wherein the method includes disposing slag within a withdrawal mold comprising a mold wall and an electrically conductive member disposed through the mold wall. A consumable electrode contacts the slag, and the slag is heated by conducting an electrical current through the consumable electrode into the slag, thereby melting at least a portion of the consumable electrode in contact with the slag. At least a fraction of the melted portion of the consumable electrode is collected in the withdrawal mold to form the ingot. At least a portion of the electrical current is conducted from the slag through the electrically conductive member.

[00010] Another aspect of the present disclosure is directed to an additional electroslag remelting method for producing a metallic ingot, wherein the method includes disposing slag within a withdrawal mold comprising a mold wall, and contacting the slag with a consumable electrode. The slag is heated by conducting an electrical current through the slag, thereby melting at least a portion of the consumable electrode in contact with the slag. At least a fraction of the electrical current introduced into the slag passes through an electrically

conductive portion of the mold wall and into the slag. At least a fraction of the melted portion of the consumable electrode is collected in the withdrawal mold to form the ingot.

[00011] Yet another aspect of the present disclosure is directed to a further electroslag remelting method for producing a metallic ingot, wherein the method includes disposing slag within a withdrawal mold comprising a mold wall and an electrically conductive member disposed through the mold wall. A consumable electrode contacts the slag. An electrical current is introduced into the slag, thereby melting at least a portion of the consumable electrode in contact with the slag. At least a fraction of the electrical current introduced into the slag passes through a region of the mold wall and into the slag, and at least a fraction of the electrical current exits the slag through the electrically conductive member. A least a fraction of the melted portion of the consumable electrode is collected in the withdrawal mold to form the ingot.

[00012] The present disclosure also is directed to novel electroslag remelting apparatus. For example, one aspect of the present disclosure is directed to an electroslag remelting apparatus including: a power source; an open-bottomed mold including a mold wall and an electrically conductive member disposed through the mold wall, wherein the electrically conductive member is in electrical communication with the power source; and an electrode feed mechanism adapted to advance an electrode toward the open-bottomed mold. The apparatus optionally includes an ingot cooling mechanism, such as, for

example, at least one fluid dispensing nozzle, disposed on an internal wall of the mold.

[00013] Yet another aspect of the present disclosure relates to an electroslag remelting apparatus including: a power source; an open-bottomed mold including a mold wall, wherein at least a portion of the mold wall is in electrical communication with the power source; and an electrode feed mechanism adapted to advance an electrode toward the open-bottomed mold. The apparatus optionally includes an electrically conductive member disposed through the mold wall and in electrical communication with the source of electrical power. The apparatus optionally includes an ingot cooling mechanism, such as, for example, at least one fluid dispensing nozzle, disposed on an internal wall of the mold.

[00014] The various methods and apparatus disclosed herein may be used to reduce macro-segregation in certain segregation-prone metallic alloys, although use of the methods and apparatus are not so restricted. Non-limiting examples of metallic alloys it is believed may be processed using the methods and apparatus described herein include certain iron-, nickel-, and cobalt-base alloys, including certain nickel-base superalloys such as alloy 718.

[00015] The reader will appreciate the foregoing details and advantages of the present disclosure, as well as others, upon consideration of the following detailed description of embodiments. The reader also may comprehend additional details and advantages of the present disclosure upon making and/or using the method and/or the apparatus set forth in the disclosure.

BRIEF DESCRIPTION OF THE FIGURES

[00016] Figures 1 and 1a schematically depict an embodiment of an ESR apparatus for carrying out a method set forth in the present disclosure wherein melt current passing through the electrode is partially diverted through a side wall of the withdrawal mold with the aid of a hot current conductor, and wherein auxiliary ingot cooling is provided within the withdrawal mold in a region in which a gap has formed between the ingot and the mold wall.

[00017] Figures 2 and 2a depict another embodiment of an ESR apparatus for carrying out a method set forth in the present disclosure wherein melt current passes to the slag through both the electrode and an upper portion of the split mold, and wherein auxiliary ingot cooling is provided within the withdrawal mold in a region in which a gap has formed between the ingot and the mold wall.

[00018] Figure 3 provides computer-simulated results comparing molten pool depths in conventional ESR (left) and in an embodiment of the method of the present disclosure wherein the melt current is at least partially diverted through a side wall of the withdrawal mold via a hot current conductor and auxiliary cooling is used. Results were obtained at an electrode melt rate of 10 lbs./minute (0.076 kg/second).

[00019] Figure 4 provides computer-simulated results comparing molten pool depths in conventional ESR (left) and in an embodiment of the method of the present disclosure wherein at least a portion of the melt current introduced into the slag passes through an upper portion of the split mold and auxiliary

cooling is used. Results were obtained at an electrode melt rate of 10 lbs./minute (0.076 kg/second).

DETAILED DESCRIPTION OF EMBODIMENTS OF THE DISCLOSURE

[00020] Each of the non-limiting embodiments described herein is believed to be useful in the manufacture of large diameter ingots of metallic (*i.e.*, metal-containing*)* alloys, wherein use of conventional ESR methods would result in macro-segregation within the ingot. It will be understood, however, that the use of the embodiments described herein is not so limited, and the embodiments may be employed in, for example, the production of metallic ingots of any size, including large diameter ingots. As noted above, as used herein, "large diameter" refers to diameters greater than 16 inches (about 0.40 m). Thus, for example, and without limiting the present disclosure in any way, ingots having diameters of 20 inches (about 0.508 m) and 38 inches (about 0.965 m) may be made according to methods disclosed herein. Also, as used herein, "metallic ingot" and "metallic alloy" refer to, respectively, an ingot and an alloy that are at least partially composed of metal.

[00021] By way of example only, and without limiting the present disclosure, ingots of any iron-, nickel-, or cobalt-base alloy can be processed using the methods and apparatus described herein. As used herein, the terms "iron-base alloy", "nickel-base alloy" and "cobalt-base alloy", respectively, refer to alloys wherein the element present in the greatest weight concentration within the alloy is iron, nickel and cobalt. One example of a nickel-base superalloy that

can be processed using the methods and apparatus described herein has the following composition: 0 to 0.08 weight percent carbon; 0 to 0.35 weight percent manganese; 0 to 0.35 weight percent silicon; 0 to 0.015 weight percent sulfur; 0 to 0.015 weight percent phosphorus; 17.0 to 21.0 weight percent chromium; 50.0 to 55.0 weight percent nickel; 0 to 1.0 weight percent cobalt; 2.8 to 3.3 weight percent molybdenum; 0.65 to 1.15 weight percent titanium; 0.20 to 0.8 weight percent aluminum; 0 to 0.006 weight percent boron; at least one of niobium and tantalum, the sum of the weights of niobium and tantalum being 5.0 to 5.5 weight percent; iron; and incidental impurities. All such weight percentages are based on the total weight of the alloy. The alloy is commercially available, for example, as Allvac® 718 alloy, from Allvac, Monroe, North Carolina. Other alloys that can be processed using the methods and apparatus disclosed herein include, for example, Allvac® 706 alloy (UNS N09706), Nickelvac® 625 alloy (UNS N06625), Allvac® Rene 41® alloy (UNS N07041), Allvac® Waspaloy® alloy (UNS N07001) and Allvac® 720 alloy (UNS N07720). In addition, the present methods and apparatus can be used to process specialty steels such as, for example, Nickelvac® 410/403 (UNS S41000), Nickelvac® 422 alloy (UNS S42200), Nickelvac® 17-4 PH alloy (UNS S17400), Nickelvac® 15-5 alloy (UNS S15500), Nickelvac® A-286 alloy (UNS S66286), Allvac® M-50 alloy (UNS T11350), Allvac® 13-8Mo alloy (UNS S13800) and Nickelvac® A-286 alloy (UNS S66286).

[00022] Figure 1 schematically depicts an embodiment of an ESR apparatus (1) according to the present disclosure useful for forming, for example, large diameter ingots. It is contemplated that a conventional ESR apparatus can

be modified to operate as shown in Figure 1 so as to provide for the manufacture of large diameter ingots of Alloy 718 and other alloys without undesirable macro-segregation.

[00023] The ESR apparatus (1) of Figure 1 includes an open-bottomed, water-cooled copper withdrawal mold (2). Slag (4) is disposed within the withdrawal mold (2). Any slag suitable for conventional ESR melting of the specific alloy being processed may be used. With respect to the ESR melting of Alloy 718, suitable slags include, but are not restricted to, compositions such as 70/15/0/15 (70% CaF_2/ 15% CaO/ 0% MgO/ 15% Al_2O_3) and other slag compositions that may contain special additives such as SiO_2. A source of electrical power (7) is also provided, which is typically alternating current (AC) and up to 30 kA in magnitude. The power source is electrically connected to and applies a current through a consumable electrode (6) of the alloy. The current passes through the consumable electrode (6) and into the slag (4), causing the slag (4) to increase in temperature and melt. As such, the current may be referred to herein as the "melt current". The electrode (6) melts when contacting the molten slag (4). After passing through the consumable electrode (6) and into the slag (4), at least a portion of the melt current is diverted through a hot current conductor (8) within the sidewall of the mold (2). As shown in Figure 1, the hot current conductor (8) is disposed intermediate an upper portion (3) and a lower portion (5) of the mold (2). Electrical insulators (18) are interposed between the hot current conductor (8) and the upper and lower portions (3,5) of the mold (2) to prevent conduction of current directly between the hot current conductor (8)

and the sidewall of the mold (2). As used herein, "hot current conductor" refers to any electrically conductive structure of suitable configuration and composition for the ESR process capable of carrying a portion of the melt current. Thus, for example, the hot current conductor may be constructed of graphite and/or suitable refractory metals. The hot current conductor (8) also is suitably constructed so that the molten slag (4) does not solidify on the hot current conductor (8) to any appreciable degree. Those of ordinary skill, upon consideration of the present disclosure, will be able to suitably configure hot current conductors that can be used in the methods and apparatus described herein.

[00024] The ESR apparatus embodiment shown in Figure 1 differs from a conventional ESR apparatus by diverting at least a portion of the melt current through a mold sidewall by way of a hot current conductor. In a conventional ESR apparatus, substantially the entire melt current passes through the slag, into the molten metal pool, through the mushy zone and into the solidified portion of the ingot. However, passing substantially the entire melt current through the mushy zone of the ingot impedes cooling and formation of the solidified ingot. Because a portion of the melt current in the ESR apparatus of Figure 1 does not pass through the mushy zone (14) of the ingot (12), the mushy zone (14) "freezes" more quickly than in a conventional ESR apparatus. In turn, the volume of the mushy zone is less than would exist in a conventional ESR apparatus under the same general conditions. The inventors believe that the increased rate of freezing of the mushy zone provided by way of the apparatus

and methods described herein does, in certain embodiments of the present disclosure, produce a substantially homogeneous ingot, even when producing ingots of large diameters, without the macro-segregation problems commonly associated with production of large diameter ingots by conventional ESR.

[00025] Thus, one embodiment of the present method provides an ESR apparatus having a melt current path from the power source (5), through the electrode (6), through the molten slag (4) and out through a wall of the mold (2) via an electrically conductive member in the form of a hot current conductor (8). To establish the current return to the power source (7) through the sidewall of the mold (2) at the mold/slag interface, hot current conductor (8) is positioned below the surface of the molten slag. A portion of the melt current may travel through a path including the base plate (13) on which the ingot (12) rests and back to the power source (7). The current paths are shown by arrows in Figure 1.

[00026] Referring to the inset portion of Figure 1, as the ingot (12) cools it contracts in diameter. Shrinkage of the ingot (12) results in a gap between the sidewall (15) of the ingot (12) and an internal wall (2a) of the withdrawal mold (2). This gap allows for the implementation of an auxiliary cooling mechanism (16) disposed in the internal wall (2a) of the withdrawal mold (2). Again referring to Figure 1, the auxiliary cooling mechanism (16) may implement quenching of the ingot surface with a fluid such as, for example, a liquid (such as water) or a gas (such as helium, argon, nitrogen, steam, or air). Auxiliary cooling is included in the apparatus of Figure 1 so as to increase the cooling rate of the ingot (12) and thereby further inhibit alloy segregation. As illustrated in Figure 1a, and as an

example only, such auxiliary cooling may be provided by an arrangement of gas or liquid dispensing nozzles (16) that are an integral part of the internal wall (2a) of the withdrawal mold (2) and arranged symmetrically around the bottom portion (5) of the withdrawal mold (2).

[00027] Although the embodiment of Figure 1 allows for passage of melt current through the sidewall of the mold and through the base of the ingot, it will be understood that other embodiments of the methods and apparatus described herein may allow for passage of melt current only or primarily through the sidewall of the mold. It will be further understood that auxiliary cooling implemented in the gap between the mold wall and the ingot may be utilized in each such embodiment, and also may be implemented in a conventional ESR apparatus wherein substantially the entire melt current passes through the base of the ingot and does not pass through the mold sidewall.

[00028] Figure 2 shows another embodiment of an ESR apparatus (1') useful for producing, for example, large diameter metallic ingots. A two-portion open-ended withdrawal mold (2') is shown, with a slag (4') disposed within the mold (2'). A consumable electrode (6') is positioned within the mold (2') and in contact with the slag (4'). The upper portion (3') and lower portion (5') of the mold (2') are electrically isolated from one another by an electrical insulator (18'). An electrical power source (7') also is employed. Unlike a conventional ESR apparatus, in the apparatus of Figure 2 melt current passes from the power source (7') and into the slag (4') through the upper portion (3') of the mold (2'), as well as the through the consumable electrode (6'). The current paths are shown

by arrows in Figure 2. The electrical insulator (18') prevents passage of melt current between the upper portion (3') and lower portion (5') of the mold (2').

[00029] By partitioning at least a portion of the incoming current through the upper portion (3') of the mold (2') in the embodiment of Figure 2, a current path is provided from the mold (2') to the slag (4') that does not pass through the electrode (6'). In this way, heating of the slag (4') is made less dependent on the immersion depth of the electrode (6') in the slag (4'). In other words, the heating of the slag (4') is less dependent on current passing into the slag (4') from the consumable electrode (6'). This makes it possible to melt the electrode (6') under more stable conditions, even at low melt rates, unlike with conventional ESR apparatus. The capability to utilize low melt rates in a more stable manner allows for less heating of the molten pool (10'), which may result in shallower molten pools than possible using a conventional ESR apparatus under the same conditions. A shallower molten pool results in a mushy zone (14') of reduced volume. Because the mushy zone (14') can be smaller than it would be with a conventional ESR apparatus, the mushy zone (14') also cools more quickly.

[00030] The cooling rate of the mushy zone (14') also may be further enhanced by the diversion of current from the slag (4') through the lower portion (5') of the mold (2'). Introduction of melt current through the mold's upper portion (3') and removal of melt current from the slag (4') through the mold's lower portion (5') is possible due to the presence of the electrical insulator (18') between the portions. As stated above, the electrical insulator (18') prevents current from passing directly between the upper (3') and lower (5') portions of the

mold (2'). This feature differs from a conventional ESR apparatus, wherein an undivided mold would be generally uniform in temperature and melt current would typically pass from the consumable electrode, through the molten pool, through the mushy zone and ultimately through the solidified portion of the ingot. The current partitioning feature of the embodiment of Figure 2 thereby may enhance cooling of the mushy zone (14'). As discussed previously, increasing the cooling rate of the mushy zone (14') inhibits segregation of alloying elements within the ingot (12').

[00031] Again referring to Figure 2, as the ingot (12') cools, it undergoes thermal contraction, resulting in a decrease in diameter. Shrinkage of the ingot (12') results in a gap forming between the sidewall (15') of the ingot (12') and the internal wall (2a') of the withdrawal mold (2'). This gap allows for the implementation of an auxiliary cooling mechanism (16') disposed in the internal wall (2a') of the withdrawal mold (2'). The auxiliary cooling mechanism (16') may be, for example, identical to that described for use in connection with the embodiment of Figure 1. This auxiliary cooling mechanism (16') increases the cooling rate of the ingot (12'), thus further inhibiting ingot segregation.

[00032] It should also be noted that the ESR apparatus and methods described in conjunction with the embodiments of Figures 1 and 2 may be performed alone or in conjunction with one another. For example, ESR apparatus (1) illustrated in Figure 1 may be suitably configured such that all of the melt current introduced into the slag (4) passes from the slag (4), through the hot current conductor (8) and back to the power source (7) to complete the

circuit. In addition, ESR apparatus (1') illustrated in Figure 2 may be suitably configured such that all of the melt current passes into the slag (4') through the upper portion (3') of the mold (2') and does not travel into the slag (4') through the electrode (6'). In yet another possible embodiment of an ESR apparatus constructed according to the present disclosure, at least a fraction of the melt current pass through a portion or region of the mold wall into the slag, and at least a fraction of the melt current exits the slag through a conductive member disposed through the mold wall. Further, in each of the various methods and apparatus described herein, the cooling of the ingot may occur in a conventional fashion or may be augmented by the use of an auxiliary cooling arrangement as generally described herein.

[00033] Figure 3 provides a computer-simulated comparison of the pool depths of a consumable electrode of Alloy 718 melted via conventional ESR (left) relative to depths using a consumable electrode of the same composition melted by a method set forth in the present disclosure wherein melt current that has passed through the consumable electrode is then partially diverted through a sidewall of the mold, and wherein the mold sidewall also implements auxiliary cooling as contemplated herein. Both simulations assume a melt rate of 10 lbs./min (0.076 kg/s). By partitioning a portion of the melt current away from the molten pool, the mushy zone and the solidified ingot, and by employing auxiliary cooling, the cooling rate of each of these regions is increased. The simulation using a method of the present disclosure predicts a shallower molten metal pool and a shallower mushy zone than predicted if processing the alloy by

conventional ESR. As previously described, an increased rate of cooling, particularly in the mushy zone, is predicted to enhance homogeneity of the ingot, correspondingly reducing segregation within the ingot.

[00034] Figure 4 shows a computer-simulated comparison between an Allvac 718 alloy treated by conventional ESR and an alloy of the same composition treated by a method of the present disclosure wherein current is partitioned such that a substantial portion of the melt current that would normally pass into the slag from the consumable electrode in conventional ESR, instead passes into the slag from a top portion of the mold. Through a combination of altering the current distribution within the slag and providing auxiliary cooling in the mold, a shallower molten pool and a shallower mushy zone is predicted as compared to conventional ESR. It is believed that this would result in an increased cooling rate in the ingot, including the mushy zone, relative to conventional ESR under the same conditions, and is predicted to enhance ingot homogeneity and correspondingly reduce segregation within the ingot.

[00035] Ingots made by the methods and apparatus disclosed herein may be used in the production of various articles of manufacture. By way of example only, such articles include high strength components for jet engines made from forgings, castings, and bar stock; welded and fabricated sheet-metal parts; fasteners; liquid rocket components involving cryogenic temperatures, such as engines, nozzles, combustion and FGD systems, afterburner and spray bars; CPI & nuclear pumps; heat exchangers; tubing; land-based turbine wheels and spacers; torque rings; turbine compressor blades, discs, shafts, spacers, and

wheels; bolts; parts for steam and gas turbines; aircraft and missile fittings; gears; superchargers; missile components; cryogenic equipment; corrosive deep well hardware; bearings, including turbine engine main shaft bearings; cutting tools; airframe structural parts; valve parts; and chemical process equipment. Methods for manufacturing such articles from ingots of particular alloys are generally known to those of ordinary skill in the art. Accordingly, further detailed discussion regarding such manufacture is unnecessary.

[00036] It is to be understood that the present description illustrates those aspects relevant to a clear understanding of the disclosure. Certain aspects that would be apparent to those skilled in the art and that, therefore, would not facilitate a better understanding have not been presented in order to simplify the present disclosure. Although the present disclosure has been described in connection with certain embodiments, those of ordinary skill in the art will, upon considering the foregoing disclosure, recognize that many modifications and variations may be employed. It is intended that the foregoing description and the following claims cover all such variations and modifications.